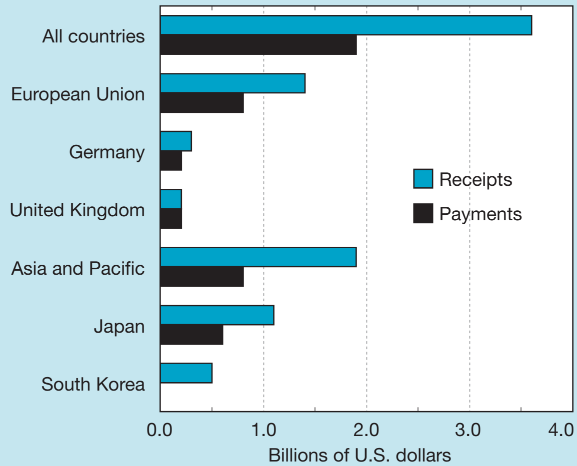
Figure 6-13.
**U.S. royalties and fees generated from the exchange of industrial processes between unaffiliated companies: 1999**




See appendix table 6-7. *Science & Engineering Indicators – 2002*

counted for more than 44 percent of total receipts in 1999.

Until 1994, U.S. trade with Europe in intellectual property, unlike trade with Asia, fluctuated between surplus and deficit. In 1994, a sharp decline in U.S. purchases of European technical know-how led to a considerably larger surplus for the United States compared with earlier years. The following year showed another large surplus resulting from a jump in receipts from the larger European countries. In 1999, receipts from European Union (EU) countries represented about 35 percent of U.S. technology sold as intellectual property, more than double the share in 1993. Some of this increase is attributable to increased licensing by firms in Germany, the third largest consumer of U.S. technological know-how. In 1999, Germany's share rose to 9.3 percent, up from 6.9 percent in 1998 and more than double its share in 1993. These latest data show receipts from France and Sweden rising sharply during the late 1990s, causing a considerably larger surplus from U.S. trade with Europe in intellectual property in 1998 and 1999.

U.S. firms have purchased technical know-how from different foreign sources over the years, with increasing amounts coming from Japan, which since 1992 has been the single largest foreign supplier of technical know-how to U.S. firms. About one-third of U.S. payments in 1999 for technology sold as intellectual property were made to Japanese firms. Europe accounts for slightly more than 44 percent of the foreign technical know-how purchased by U.S. firms; the United Kingdom and Germany are the principal European suppliers.[13]

## New High-Technology Exporters

Several nations have made tremendous technological leaps forward over the past decade. Some of these countries are well positioned to play more important roles in technology development because of their large and continuing investments in S&E education and R&D.[14] However, their success may hinge on other factors as well, including political stability, access to capital, and an infrastructure that can support technological and economic advancement.

This section assesses a group of selected countries and their potential to become more important exporters of high-technology products during the next 15 years, based on the following leading indicators:

- **National orientation—**evidence that a nation is taking action to become technologically competitive, as indicated by explicit or implicit national strategies involving cooperation between the public and private sectors.
- **Socioeconomic infrastructure—**the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to the functioning of a modern, technology-based industrial nation. Indicators include the existence of dynamic capital markets, upward trends in capital formation, rising levels of foreign investment, and national investments in education.
- **Technological infrastructure—**the social and economic institutions that contribute directly to a nation's ability to develop, produce, and market new technology. Indicators include the existence of a system for the protection of intellectual property rights (IPR), the extent to which R&D activities relate to industrial application, competency in high-technology manufacturing, and the capability to produce qualified scientists and engineers.
- **Productive capacity—**the physical and human resources devoted to manufacturing products and the efficiency with which those resources are used. Indicators include the current level of high-technology production, the quality and productivity of the labor force, the presence of skilled labor, and the existence of innovative management practices.

This section analyzes 15 economies: 6 in Asia (China, India, Indonesia, Malaysia, the Philippines, and Thailand); 3 in Central Europe (Czech Republic, Hungary, and Poland); 4 in Latin America (Argentina, Brazil, Mexico, and Venezuela); and 2 others (Ireland and Israel) that have shown increased technological activity.[15]

### National Orientation

The national orientation indicator identifies nations whose businesses, government, and culture encourage high-technology development. This indicator was constructed using information from a survey of international experts and published

[13]Over the years, France has also been an important source of technological know-how. In 1996, France was the leading European supplier to U.S. firms. Since then, data on France have been suppressed to avoid disclosing individual company operations.

[14]See chapter 2 for the discussion of international higher education trends and chapter 4 for the discussion of trends in international R&D.

[15]See Porter and Roessner (1991) for details on survey and indicator construction; see Roessner, Porter, and Xu (1992) for information on the validity and reliability testing the indicators have undergone.

data. The survey asked the experts to rate national strategies that promote high-technology development, social influences favoring technological change, and entrepreneurial spirit. Published data were used to rate each nation's risk factor for foreign investment during the next five years (PRS Group 1999).

Ireland and Israel posted the highest overall scores by far on this indicator. (See figure 6-14 and appendix table 6-8.) Although Ireland scored slightly lower than Israel on each of the expert-opinion components, its rating as a much safer place for foreign investment than Israel elevated its composite score.

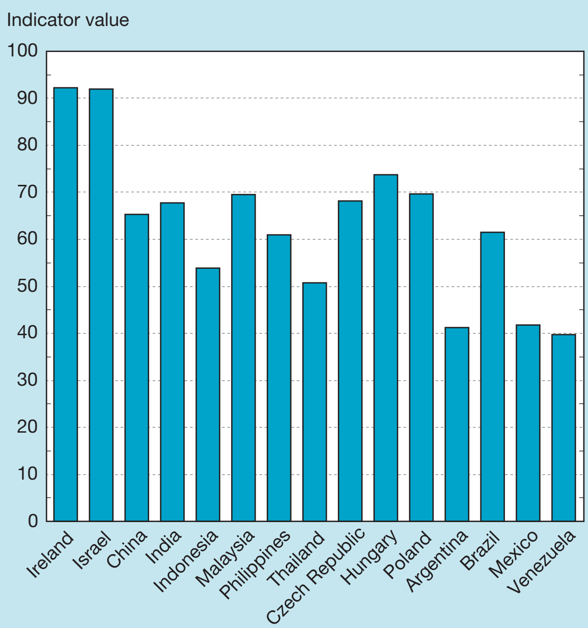
The national orientation of both Ireland and Israel was scored consistently and significantly higher than that of the other countries examined and was well within the range of scores accorded the more advanced economies of Taiwan and Singapore. Hungary, Poland, and Malaysia also scored well, with strong scores in each of the indicator components.

Except for Brazil, the Latin American countries (Argentina, Mexico, and Venezuela) received the lowest composite scores of the economies examined. Two factors contributed to their low scores: they were considered riskier or less attractive sites for foreign investment than the other countries, and the experts did not consider these three countries to be entrepreneurial.

## Socioeconomic Infrastructure

The socioeconomic infrastructure indicator assesses the underlying physical, financial, and human resources needed to support modern, technology-based nations. It was built from published data on percentages of the population in secondary

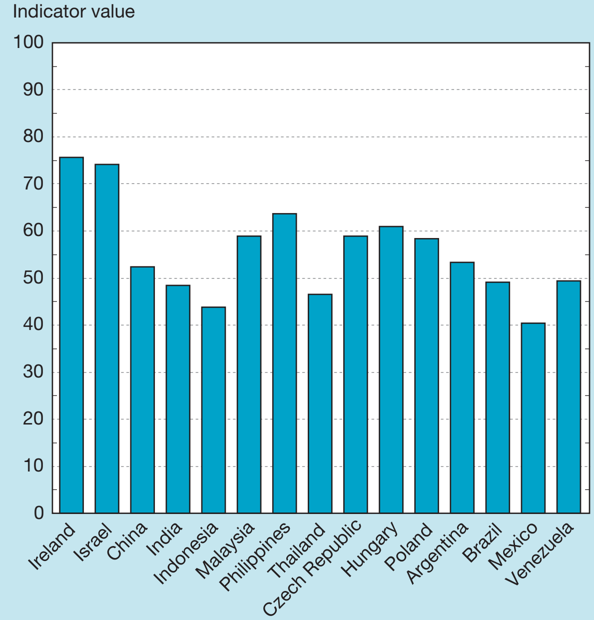
Figure 6-14.
**National orientation indicator**




NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

Figure 6-15.
**Socioeconomic infrastructure indicator**




NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

school and in higher education and survey data evaluating the mobility of capital and the extent to which foreign businesses are encouraged to invest and do business in that country.[16] (See figure 6-15.)

Ireland and Israel again received the highest scores among the emerging and transitioning economies examined. In addition to their strong track records on general and higher education, Ireland's and Israel's scores reflect their high ratings for the mobility of capital and their encouragement of foreign investment. Their scores were similar to those given to Taiwan and South Korea.

Among the remaining nations, the Philippines edged out the three Central European countries, which all posted similar scores. The socioeconomic infrastructure score for the Philippines was bolstered by its strong showing in the published education data and by the experts' higher opinion of its mobility of capital.

Mexico received the lowest composite score of the 15 nations examined. It was held back by low marks on two of the three variables: educational attainment—in particular, university enrollments—and the variable rating of its mobility of capital.

## Technological Infrastructure

Five variables were used to develop the technological infrastructure indicator, which evaluates the institutions and resources that help nations develop, produce, and market new

[16] The Harbison-Myers Skills Index (which measures the percentage of the population attaining secondary and higher education) was used for these assessments (World Bank 1999).

technology. This indicator was constructed using published data on the number of scientists in R&D; published data on national purchases of electronic data processing (EDP) equipment; and data from a survey that asked experts to rate each nation's ability to train its citizens locally in academic S&E, make effective use of technical knowledge, and link R&D to industry.

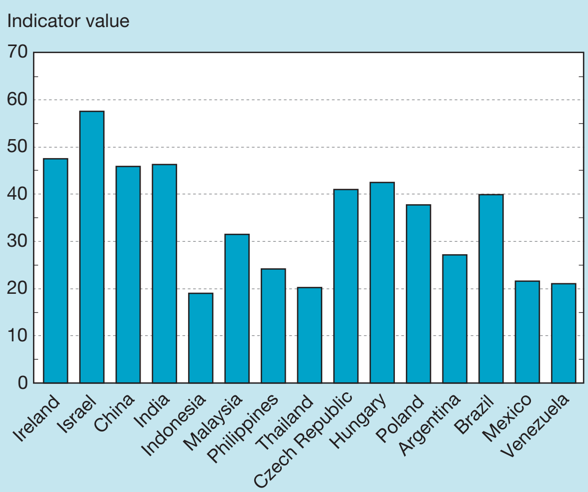
Israel received the highest composite score of the group of newly industrialized or transitioning economies examined here. (See figure 6-16.) Israel's high score on this indicator was based on its large number of trained scientists and engineers, the size of its research enterprise, and its contribution to scientific knowledge, especially compared with Ireland and the smaller, less populous nations in Asia and Central Europe. Ireland received the second highest score, followed by India and China. Ireland's score was bolstered by its large purchases of EDP equipment. India's and China's scores were nearly identical, although India's scores showed more balance across indicator components and more overall strength. China's score was influenced greatly by the two components derived from statistical data: its large purchases of EDP equipment and its large number of scientists and engineers engaged in R&D.

## Productive Capacity

The productive capacity indicator evaluates the strength of a nation's current, in-place manufacturing infrastructure as a baseline for assessing its capacity for future growth in high-technology activities. It factors in expert opinion on the availability of skilled labor, numbers of indigenous high-technology companies, and management capabilities, combined with published data on current electronics production in each country.

Ireland scored highest in productive capacity among the 15 developing and transitioning nations examined, receiving high marks for each indicator component. (See figure 6-17.) Ireland's score also was boosted by its prominence in the computer hardware manufacturing industry. India and Israel were second and third, attaining strong scores on each indicator component.

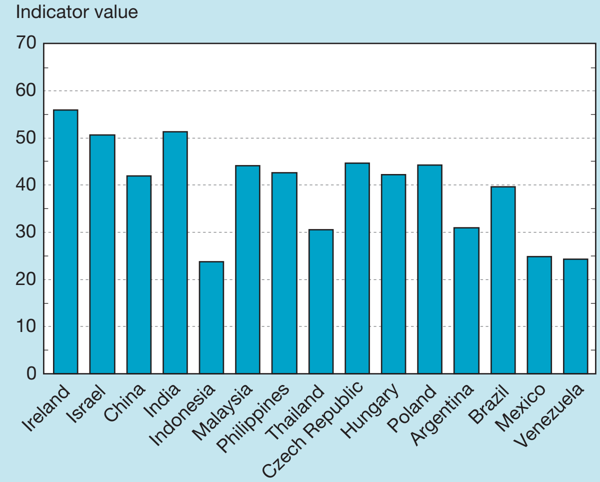
Figure 6-16.
**Technological infrastructure indicator**




NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

Figure 6-17.
**Productive capacity indicator**




NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

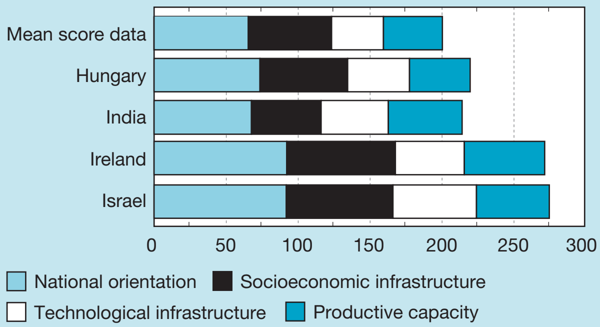
Several developing Asian economies, particularly China and Malaysia, had higher electronics production than did Ireland in 1996, the reference year for the published data. However, they scored lower on indicator components rating their labor pools and management personnel. Mexico's score showed an even greater imbalance than those of China and Malaysia. Although Mexico's production of electronics products—this indicator's published data variable—was greater than Ireland's, scores rating the quality of Mexican labor and management were extremely low. As a result, Mexico received the second lowest score of the 15 countries examined.

## Findings From the Four Indicators

Based on the set of four leading indicators discussed, Ireland and Israel appear headed toward prominence as exporters of technology products to the global market. Ireland led the group of 15 developing and transitioning countries examined in three of the four leading indicators and received the second highest score in the fourth, technological infrastructure. On that indicator, Israel ranked first because of its large number of trained scientists and engineers, its highly regarded industrial research enterprise, and its contribution to scientific knowledge. Israel placed second on two of the remaining indicators and third on the other. (See figure 6-18.)

Hungary and India also posted strong scores on at least three of the four indicators. Hungary ranked third on the indicator identifying nations that are taking action to become technologically competitive, fourth on the indicator rating socioeconomic infrastructure, and fifth on the technological infrastructure indicator. India scored nearly as well and some-

Figure 6-18.
**Composite scores for four new high-tech exporters**




NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

times better than Hungary on the leading indicators, but its scores were not as balanced. Hungary's lowest ranking on any of the four indicators was 8th on the productive capacity indicator, while India's lowest ranking was 11th on the socioeconomic indicator. India's large population helped to elevate its scores on several indicators.

These indicators provide a systematic approach for comparing future technological capability on an even wider set of nations than might be available using other indicators. The results highlight a broadening of the group of nations that may compete in high-technology markets in the future while also reflecting the large differences between several of the emerging and transitioning economies and those considered newly industrialized.

# International Trends in Industrial R&D

In high-wage countries such as the United States, industries stay competitive in a global marketplace through innovation (Council on Competitiveness 2001). Innovation leads to better production processes and higher quality products, thereby providing the competitive advantage high-wage countries need when competing against low-wage nations.

R&D activities serve as incubators for the new ideas that can lead to new products, processes, and industries. Although they are not the only source of new innovations, R&D activities conducted in industry-run laboratories and facilities are the source of many important new ideas that have shaped modern technology.[17]

U.S. industries that traditionally conduct large amounts of R&D have met with greater success in foreign markets than those that are less R&D intensive, and they have been more supportive of higher wages for their employees. (See "U.S. Technology in the Marketplace" section for a presentation of recent trends in U.S. competitiveness in foreign and domestic product markets.) Moreover, trends in industrial R&D performance are leading indicators of future technological performance. The following section examines these R&D trends, focusing particularly on growth in industrial R&D activity in the top R&D-performing industries in the United States, Japan, and the EU.[18]

## R&D Performance by Industry

The United States, the EU, and Japan represent the three largest economies in the industrialized world and are competitors in the international marketplace. An analysis of R&D data can explain past successes in certain product markets, provide insights into future product development, and highlight shifts in national technology priorities.[19]

### *United States*

R&D performance by the U.S. service-sector industries underwent explosive growth between 1987 and 1991, driven primarily by computer software firms and firms performing R&D on a contract basis. In 1987, service-sector industries performed less than 9 percent of all R&D performed by industry in the United States. During the next several years, R&D performed in the service sector raced ahead of that performed by U.S. manufacturing industries, and by 1989, the service sector performed nearly 19 percent of total U.S. industrial R&D, more than double the share held just two years earlier. By 1991, service-sector R&D had grown to represent nearly one-fourth of all U.S. industrial R&D. Since then, R&D performance in U.S. manufacturing industries increased and began growing faster than in the burgeoning service sector. Manufacturers' share inched back up to 80 percent of total U.S. industry R&D by 1996, the latest year for which internationally comparable data are available. Industries making computer hardware, electronics equipment, and motor vehicles led this resurgence in manufacturing-sector R&D. (See figure 6-19 and appendix table 6-9.)

From 1987 to 1992, the U.S. aerospace industry performed the largest amount of R&D, accounting for 14 to 26 percent of total R&D performed by industry. The industry manufacturing electronics equipment (including communications equipment) and the U.S. chemical industry (including pharmaceuticals) followed, each accounting for between 9 and 16 percent of total U.S. R&D. During the mid-1990s, however, the nation's R&D emphasis shifted; the aerospace industry's share declined, and the share for the industry manufacturing communications equipment increased. In 1996 and 1997, the industry manufacturing communications and other electronics equipment was the top R&D performer in the United States.

[17]For a discussion of trends in foreign direct investment in R&D facilities, see chapter 4.

[18]This section uses data from OECD's Analytical Business Enterprise R&D database (OECD 2000) to examine trends in national industrial R&D performance. This database tracks all R&D expenditures (both defense- and nondefense-related) carried out in the industrial sector, regardless of funding source. For an examination of U.S. industrial R&D by funding source, see chapter 4.

[19]Industry-level data are occasionally estimated here to provide a complete time series for the 1987–97 period.